

“Fly-by-Wireless” Update

Aug 24, 2010

Wing Leading Edge
with 22 Reinforced
Carbon-Carbon Panels

Example Shown: Orbiter Wing Leading Edge Impact Detection System

Wireless Data
Acquisition
Sensor Unit

Accelerometer

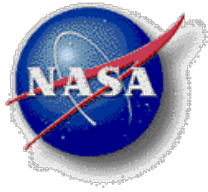
Reinforced
Carbon-Carbon
Panel

Thermal Sensor

Univ of Maine/IEEE/CANEUS Workshop
NASA/JSC/EV/George Studor
(763) 208-9283



“Fly-by-Wireless” Update

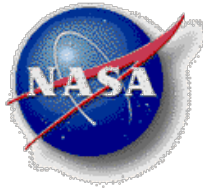


- **What do we mean by “Fly-by-Wireless”?**
- **Common Problem and Motivation**
- **Recent Examples**
- **NASA’s Future and Basis for Collaboration**



“Fly-by-Wireless”

(What is it?)



Vision:

To Minimize Cables and Connectors and Increase Functionality across the aerospace industry by providing reliable, lower cost, modular, and higher performance alternatives to wired data connectivity to benefit the entire vehicle/program life-cycle.

Focus Areas:

- 1. System engineering & integration methods to reduce cables & connectors.**
- 2. Vehicle provisions for modularity and accessibility.**
- 3. A “tool box” of alternatives to wired connectivity.**

What it is NOT:

- A vehicle with no wires.**
- Wireless-only for all control systems.**



“Fly-by-Wireless” Focus Areas



(1) System engineering and integration to reduce cables and connectors,

- **Capture the true program effects** for cabling from launch & manned vehicles.
- **Requirements** that enable and integrate alternatives to wires.
- **Metrics** that best monitor progress or lack of progress toward goals. (# cables, length, # of connectors/pins, # of penetrations, overall weight/connectivity, total data moved/lb).
- **Design Approach** that doesn't assume a wires-only approach, but optimizes all practical options, providing for the inevitable growth in alternatives to wired connectivity.

(2) Provisions for modularity and accessibility in the vehicle architecture.

- **Vehicle Zone Accessibility** – Considers standalone sensors along with system assembly, inspections, failure modes/trouble-shooting, system/environment monitoring, remove & repair.
- **Vehicle Zone Modularity** – Vehicle wired buses provide power, two-way data/commanding, grounding and time in a plug-and-play fashion. Wireless networks are standardized by function and are also plug-and-play.
- **Centralized & De-centralized approaches** are available for measurement & control.
- **Entire life-cycle** considered in addition to schedule, performance, weight & volume.

(3) Develop Alternatives to wired connectivity for the system designers and operators.

- | | |
|--|--|
| - Plug-n-Play wireless devices | - Data on power lines, light, structure, liquids |
| - Wireless no-power sensors/sensor-tags | - No connectors for bulkheads, avionics power |
| - Standalone wireless smart data acquisition | - Robust software programmable radios |
| - Standardized I/Fs, networks & operability | - Light wt coatings, shielding, connectors |
| - Wireless controls – back-up or low criticality | - RFID for ID, position, data, & sensing. |
| - Robust high speed wireless avionics comm. | - Inductive coupling for rechargeable batteries |



“Fly-by-Wireless” Activities



| | |
|---|---------------------|
| NASA/JSC “Fly-by-Wireless” Workshop | 10/13/1999 |
| USAF Reserve Report to AFRL | 11/15/1999 |
| DFRC Wireless F-18 flight control demo - Report | 12/11/1999 |
| ATWG “Wireless Aerospace Vehicle Roadmap” | 2/12/2000 |
| Office of Naval Research | 2/16/2000 |
| NASA Space Launch Initiative Briefing | 8/7/2001 |
| World Space Congress, Houston | 3/8/2002 |
| International Telemetry Conference | 4/6/2004 |
| VHMS TIM at LaRC | 5/11/2004 |
| CANEUS 2004 “Wireless Structural Monitoring Sensor Systems” | 10/28/2004 |
| Inflatable Habitat Wireless Hybrid Architecture & Technologies Project: | 9/2006 |
| CANEUS 2006 “Lessons Learned Micro-Wireless Instrumentation | 9/2006 |
| CANEUS <u>“Fly-by-Wireless” Workshop</u> to investigate the common interests | 3/27/2007 |
| NASA/AIAA Wireless and RFID Symposium for Spacecraft, Houston | May, 2007 |
| AVSI/other intl. companies organize/address the spectrum issue at WRC07 | Nov 2007 |
| Antarctic Wireless Inflatable Habitat, AFRL-Garvey Space Launch Wireless | July 2008 |
| RFIs in NASA Tech Briefs, Constellation Program Low Mass Modular Instr | May/Nov 2008 |
| Gulfstream demonstrates “Fly-by-Wireless” Flight Control | Sept 2008 |
| CANEUS 2009 “Fly-by-Wireless” Workshop | Mar 2009 |
| AFRL announces “Wireless Spacecraft” with Northrup-Grumman | Mar 2009 |
| CCSDS Wireless Working Group | Apr 2009 |
| JANNAF Wireless Sensor Workshop | Apr 2009 |
| ISA 100.11a finishes new standard for security for Industrial use | Sep 2009 |
| NASA begins Wireless Avionics Community of Practice | May 2010 |
| AVSI releases request for Agenda item at New World Radio Conference | Jun 2010 |
| CANEUS/IEEE/Univ of Maine “Fly-by-Wireless” Workshop | Aug 2010 |

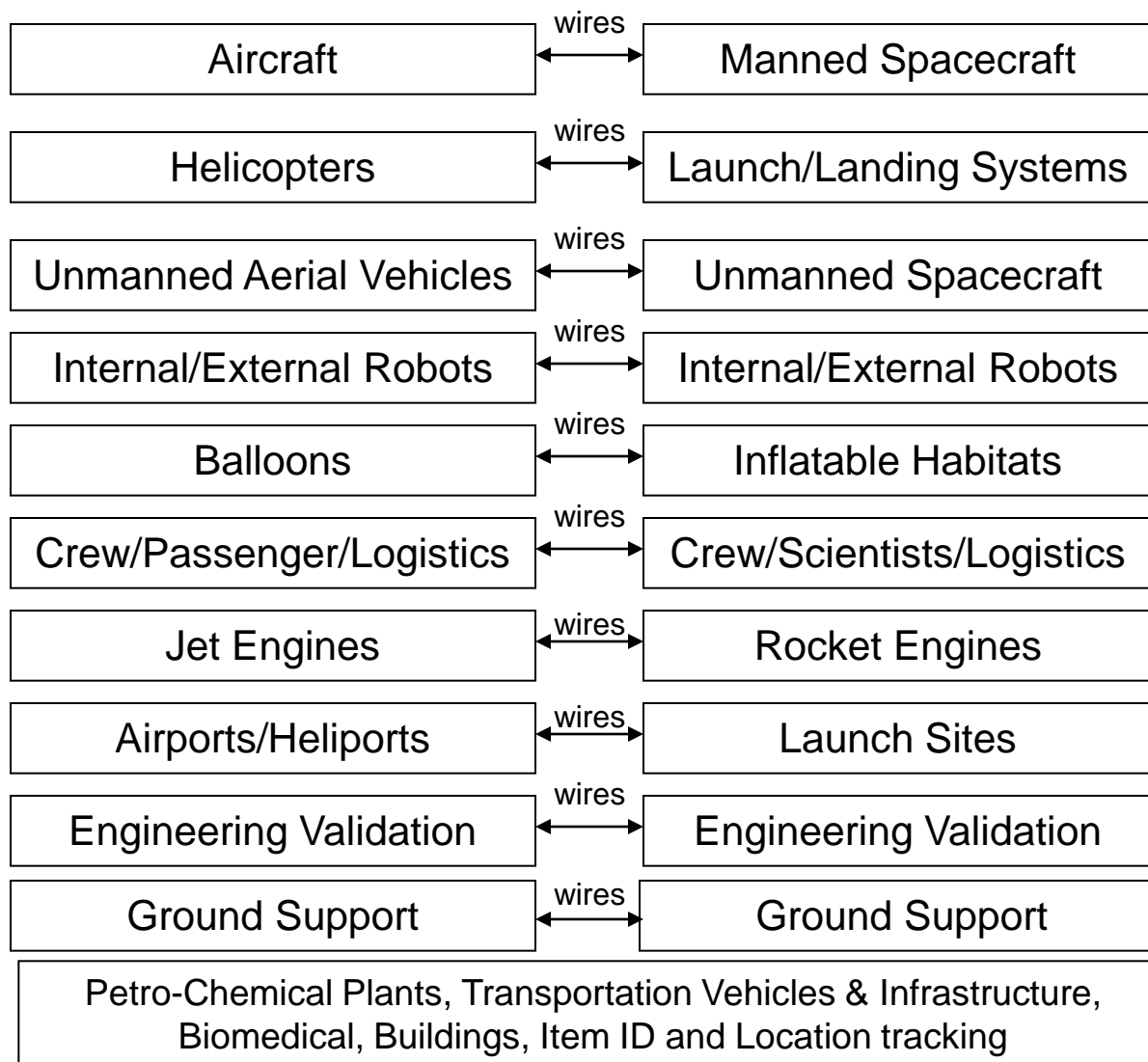


What Do the Two Industries Have in Common?

Wires!!

Aviation

Space

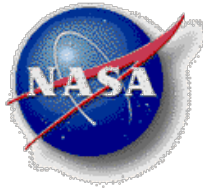


What do these have in common?

1. Data, Power, Grounding Wires and Connectors for: Avionics, Flight Control, Data Distribution, IVHM and Instrumentation.
2. Mobility & accessibility needs that restrict use of wires.
3. Performance issues that depend on weight.
4. Harsh environments.
5. Limited flexibility in the central avionics and data systems.
6. Limited accessibility.
7. Need to finalize the avionics architecture early in the lifecycle.
8. Manufacturing, pre and post delivery testing.
9. Schedule pressure, resource issues, security and reliability.
10. Operations and aging problems.
11. Civilian, military, academic & international institutions.
12. Life-cycle costs due to wired infrastructure.
13. Need for Wireless Alternatives!!



Common Motivations

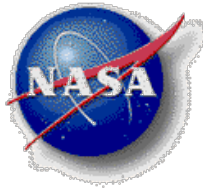


- **Reduce Cost/Schedule of Wired Connectivity**
- **Increase Reliability/Maintainability**
- **Increase Safety**
- **Increase Security (some more than others)**
- **Increase System Functionality**
- **Changes in System Engineering & Integration, Vehicle Architecture and Technology Development/Awareness**
- **Decrease Size, Weight and Power**



Motivation: The Cost of Wired Infrastructure

- Expenses for Cabled Connectivity begin in the preliminary design phase and continue for the entire life cycle.
- Reducing the quantity and complexity of the physical interconnects has a payback in many areas.
 1. Failures of wires, connectors and the safety and hazard provisions in avionics and vehicle design to control or mitigate the potential failures.
 2. Direct Costs: Measurement justification, design and implementation, structural provisions, inspection, test, retest after avionics R&R, logistics, vendor availability, etc.
 3. Cost of Data Not Obtained: Performance, analyses, safety, operations restrictions, environments and model validations, system modifications and upgrades, troubleshooting, end of life certification and extension.
 4. Cost of Vehicle Resources: Needed to accommodate the connectivity or lack of measurements that come in the form of weight, volume, power, etc.
 5. Reliability Design Limitations: Avionics boxes must build in high reliability to “make up for” low reliability cables, connectors, and sensors. Every sensor can talk to every data acquisition box, and every data acquisition box can talk to every relay box - backup flight control is easier



Motivation: The Cost of Wired Infrastructure

6. **Physical Restrictions**: Cabled connectivity doesn't always work well for monitoring: structural barriers limit physical access and vehicle resources, the assembly of un-powered vehicle pieces (like the ISS), during deployments (like a solar array, cargo/payloads, or inflatable habitat), crew members, robotic operations, proximity monitoring at launch, landing or mission operations.
7. **Performance**: Weight is not just the weight of the cables, it is insulation, bundles, brackets, connectors, bulkheads, cable trays, structural attachment and reinforcement, and of course the resulting impact on payloads/operations. Upgrading various systems is more difficult with cabled systems. Adding sensors adds observability to the system controls such as an autopilot.
8. **Flexibility of Design**: Cabling connectivity has little design flexibility, you either run a cable or you don't get the connection. Robustness of wireless interconnects can match the need for functionality and level of criticality or hazard control appropriate for each application, including the provisions in structural design and use of materials.
9. **Cost of Change**: This cost grows to make changes as each flight grows closer, as the infrastructure grows more entrenched, as more flights are "lined-up" the cost of delays due to trouble-shooting and re-wiring cabling issues can be prohibitive.



Motivation:

Cost of Change for Wired Instrumentation

The earlier that conventional instrumentation requirements and design needs to be frozen, the greater the cost of change.

- Different phases uncover and/or need to uncover new data and needs for change.
- Avionics and parts today go obsolete quickly - limited supportability, means more sustaining costs.
- The greater number of integration and resources that are involved, the greater the cost of change.
- Without mature/test systems and environments, many costly decisions result.

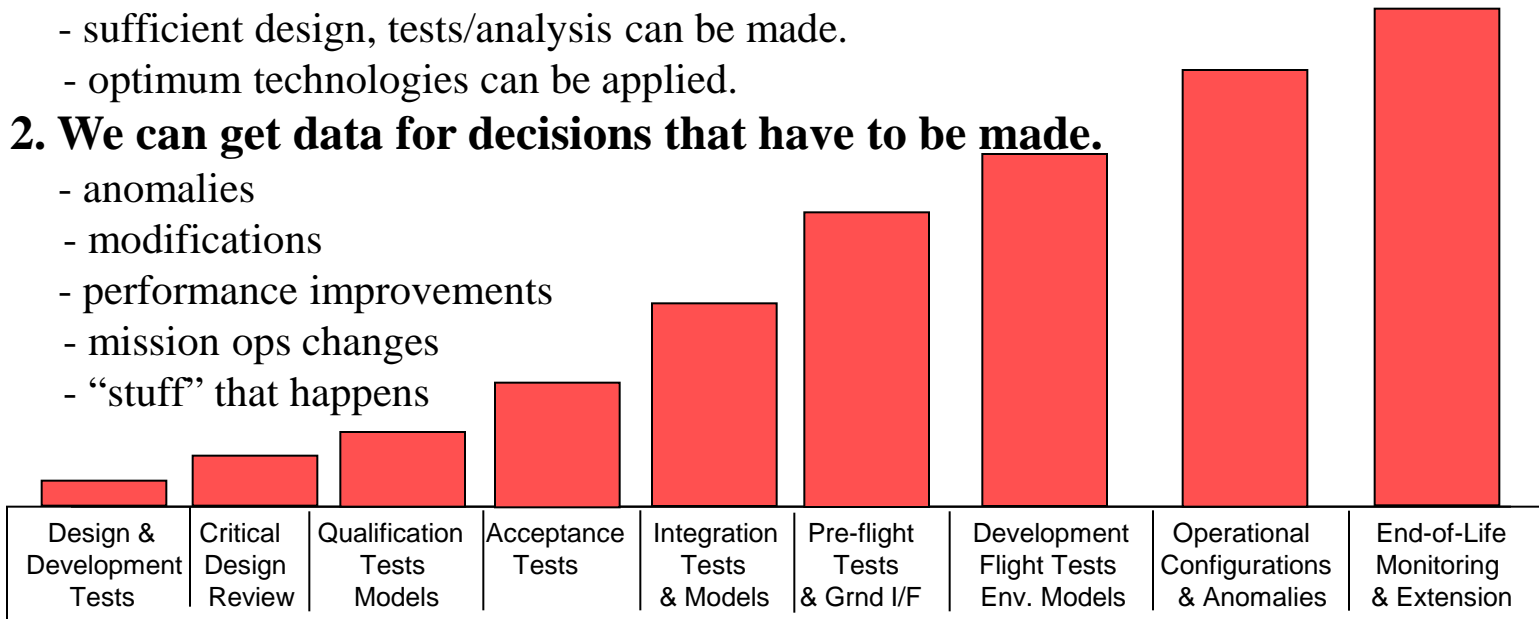
We need to design in modularity and accessibility so that:

1. We can put off some decisions until:

- sufficient design, tests/analysis can be made.
- optimum technologies can be applied.

2. We can get data for decisions that have to be made.

- anomalies
- modifications
- performance improvements
- mission ops changes
- “stuff” that happens





Motivation: Increase Vehicle Reliability

Vehicle Reliability Analyses must include: the end-to-end system, including man-in-the-loop operations, and the ability to do effective troubleshooting, corrective action and recurrence control.

With Wireless Interconnects, the overall Vehicle Reliability can be Increased:

Through Redundancy: All controllers, sensors, actuators, data storage and processing devices can be linked with greater redundancy. A completely separate access path provides greater safety and reliability against common mode failures.

Through Structural and System Simplicity: Greatly reduced cables/connectors that get broken in maintenance and must be trouble-shot, electronics problems, sources of noisy data and required structural penetrations and supports.

Through Less Hardware: Fewer Cables/Connectors to keep up with.

Through Modular Standalone Robust Wireless Measurement Systems: These can be better focused on the system needs and replaced/upgraded/reconfigured easily to newer technologies. Smart wireless DAQs reduce total data needed to be transferred.

Through Vehicle Life-Cycle Efficiency: Critical and non-critical sensors can be temporarily installed for all kinds of reasons during the entire life cycle.



Motivation: Safety

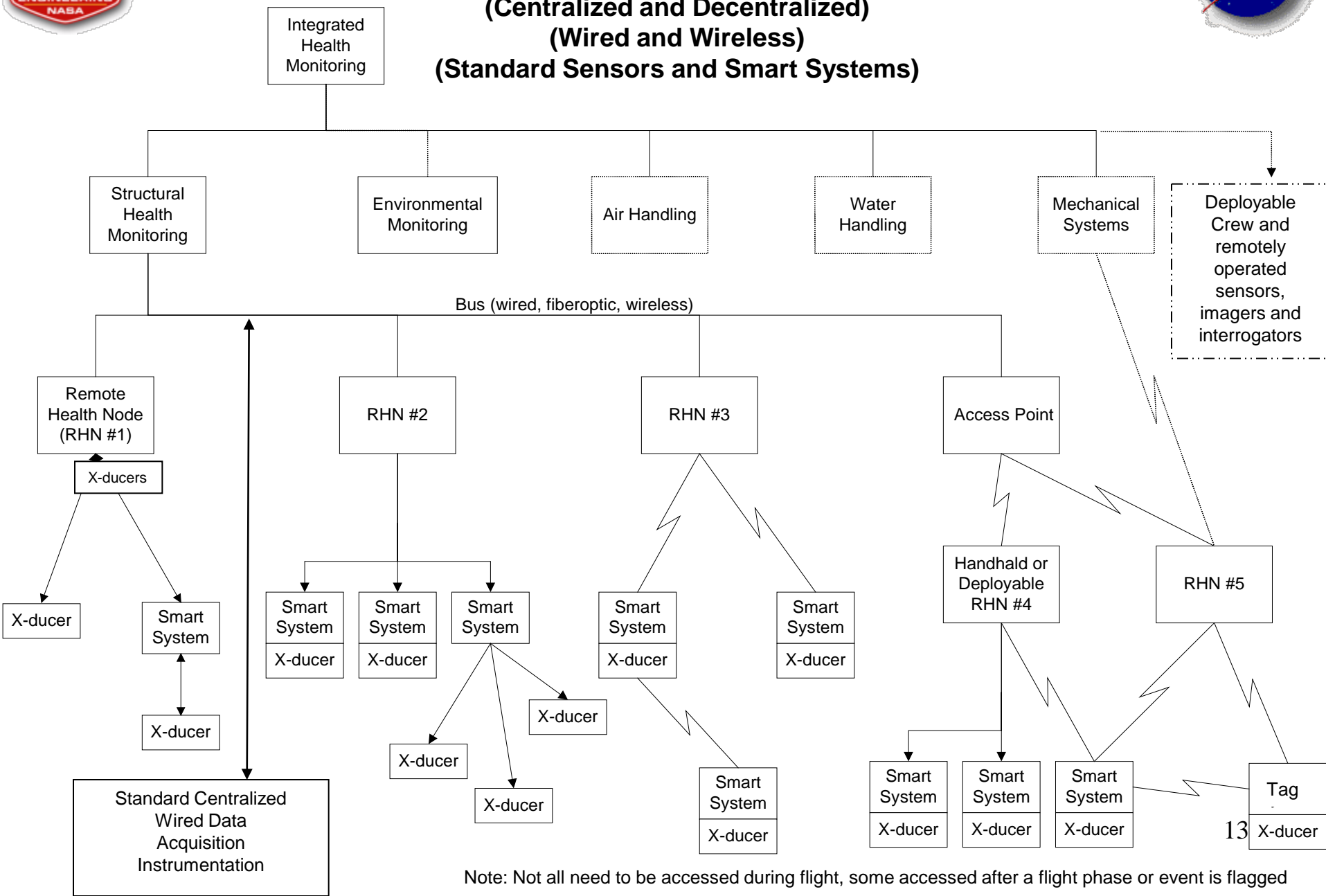


- **Reduced Response Time** to respond with changes in monitoring.
- **Increased Options** for sensing, inspection, display and control.
 - e.g. rotating equipment, human interfaces, unpowered areas.
- **Fewer Structural/Material Failure Points** - Penetrations, connectors, wiring, and sensor connection complexity.
- **Better Opportunities Correct/Upgrade** for safety deficiencies.
- **Increase redundancy** with backup and add-on systems.

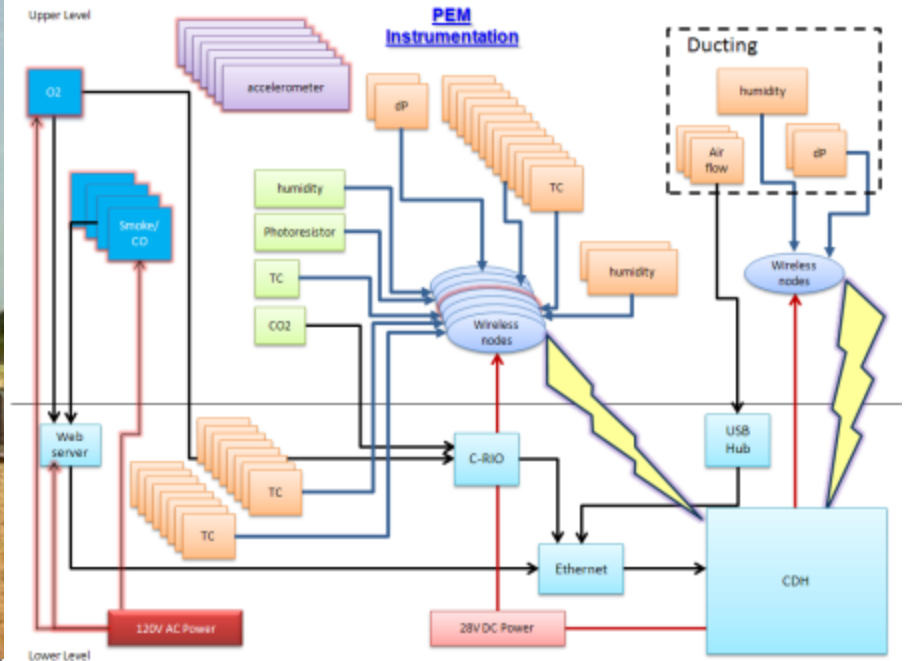


Conceptual Hybrid SMS Architecture

(Centralized and Decentralized)
(Wired and Wireless)
(Standard Sensors and Smart Systems)



JSC Habitat Development Unit with Hybrid Architecture



Habitat Sensing:

CO2, Smoke, Humidity

Air Flow, Air Pressure

Accelerometers, Temperatures

Also Wireless to Temperature in Airlock

Hybrid Instrumentation includes

JSC WSN Network of Dust-based sensor-nodes

Note: HDU is on its way to participate in the NASA "Desert RATS" testing in August.



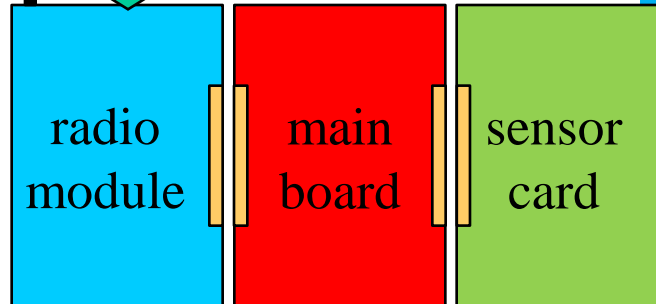
JSC Wireless Sensor Node Upgrades



Current JSC WSN with
dust protocol (TSMP)
20 made so far

Substitute New Radio Module
ISA100.11a radio (Nivis, LLC)

10 initial run, then 100 units



Note: ISA100.11a is typically
for a low data rate system

WSN ISA 100.11a Testing at JSC:

RF issues:

- Data delivery reliability
 - multi-path, interference, noise
- Data throughput rate
- Interoperability-2.4 GHz 802.11

Power issues:

- Radio/networking component
- Low power, full mesh networking
- Sensing/processing component
- Scheduled & event-driven sensing

Application issues:

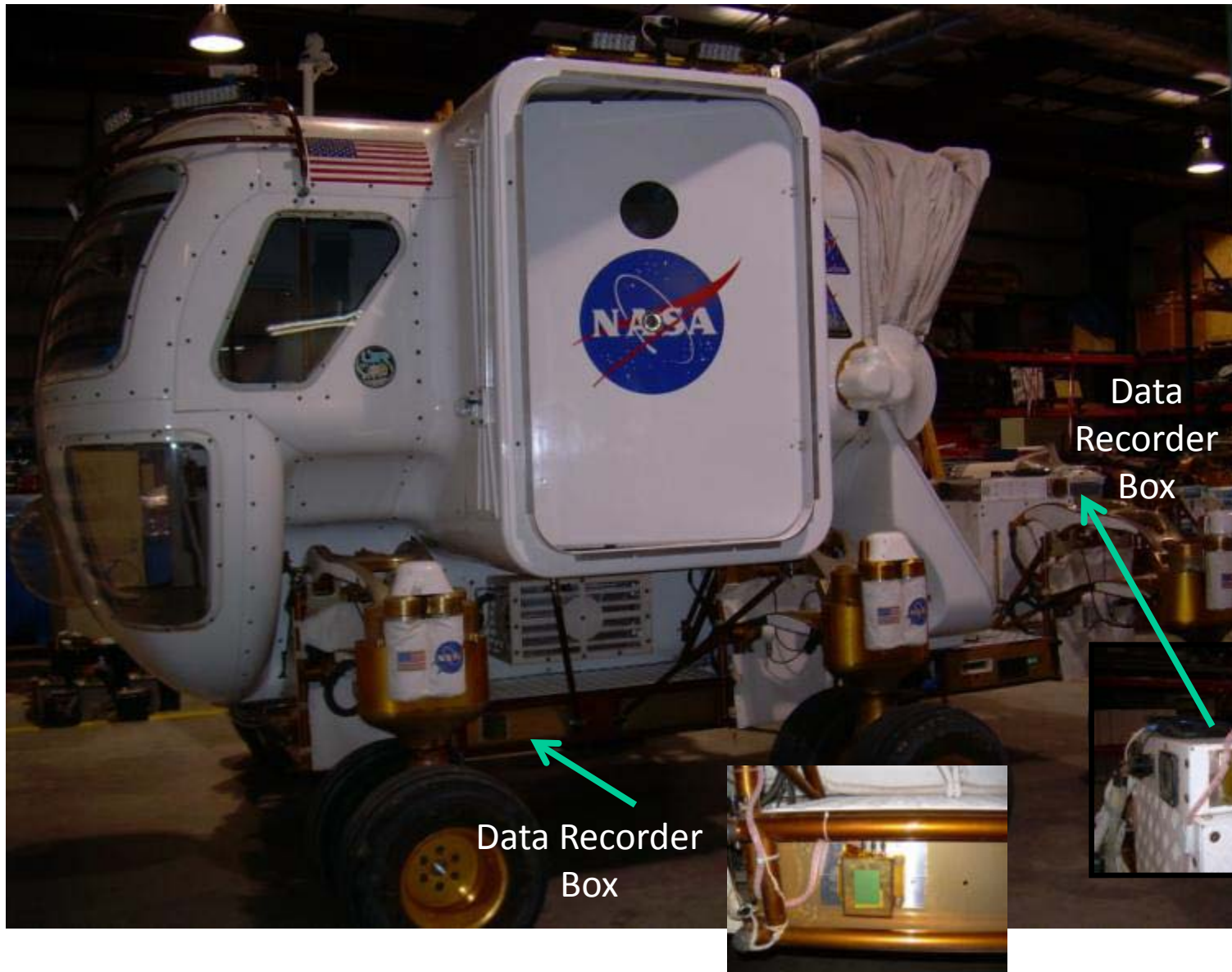
- Feasibility of sensing transients
- Usefulness of MAC-derived apps
- Time synchronization

Protocol issues:

- Which protocols best apply when?
- Modifying existing commercial protocols or using as-is
- Investigating future standards-based protocols



Lunar Electric Rover – “Desert Rats” Instrumentation Installed June 2010



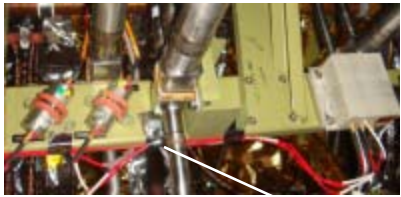


Shuttle Main Engine Ignition Acoustic Environment



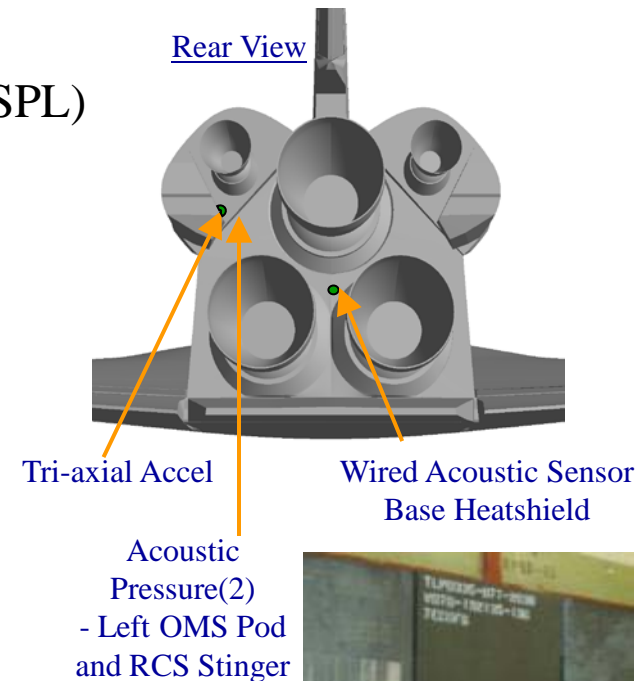
OMS Pod Loading due to Acoustic Pressure – potentially out of cert life

- Discovered at FRR, 2 weeks prior to STS-129 – Nov 2009
 - Add Triax inside OMS Pod – 20K/sec and high dynamic range
- Add Acoustic Monitoring – STS-130 and subs:
 - 20 -315Hz @ max 180 dB Sound Pressure Level (SPL)



Accelerometer Location

OV-104 WLEIDS
Recorder Location





Project M RR1 Lander



Developmental Flight Instrumentation



Wing Leading Edge Data Recorder
High Data Rate
Low Data Rate

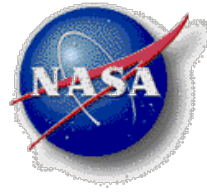


Micro Strain Gauge Unit (MSGU)



RR1 Tests at Caddo Mills, TX
Armadillo Aerospace
Tethered Lander flight test 05/22/10
Lander Free flight test 06/23/10





NASAs Future: Current Manned Spaceflight Challenges

- **Space Shuttle:**

- Monitoring for safety of flight thru end of program
- Use of Shuttle assets after it is retired

- **ISS:**

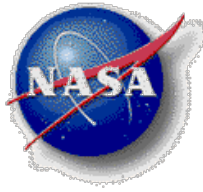
- Long term maintainability – all systems
- Increased scope of on-orbit structural validation
- Rapid module leak location system
- ISS utilization increases – HD video, wireless audio, other WLAN needs
 - Drag-thru cables that impede rapid hatch closures
- Need a new transportation method for getting to ISS post-Shuttle retirement

- **Future Programs:**

- Ground test instrumentation, development flight test instrumentation
- Operational flight instrumentation and deployments with EVA/robotic missions
- Weight, power and volume reductions for vehicle and wireless systems
- Standardization of wireless interfaces and systems



What's Needed?



1. **Communication** of needs and capabilities → Link the “Communities of Practice”
 - **Personal investment:** News items/alerts, email and web-based networks
 - **RFIs** – Such as the flurry of them that happened this summer
<http://nspires.nasaprs.com/external/solicitations/solicitations.do?method=init>
 - **RFPs** – SBIR/STTR Cycles, Challenges, Space Grant, etc.
<http://sbir.gsfc.nasa.gov/SBIR/sbirsttr2010/solicitation/index.html>
 - **IPP Seed fund:** http://www.nasa.gov/offices/ipp/technology_infusion/seed_fund/index.html
 - **NASA website(s)** – Chief Engineer/Communities of Practice; Office of Chief Technologist
 - **Other agencies** – DOD, DOE, DOT, NIH, DHS
 - **Industries:** Oil and Gas; Aerospace; Medical; Transportation; Construction; Home
2. **Business case studies:** Cost – Benefit of Wires/Wireless; Metrics
3. **Evaluate various “less-wire” technologies that are already being developed**
 - Cooperative exchange of testing, results and hardware/systems.
 - Use real world environments and test scenarios to solve a real problem.
4. **Architecture studies:** Provisions for wireless, System Engineering Texts
5. **Create the Wireless “Tool Box” - some priorities**
 - **Smart Sensor-DAQ Micro-Miniaturization** – Ex: WLEIDS → System on a chip, Plug-n-play
 - **Passive Wireless Sensor-Tag systems** – increase channels, sensor types, miniaturize interrogator, work in typical avionics bays,
 - **Extremely High Data Rate LANs** for video and other sensors –VLAN is emerging
 - **Standardized and Ruggedized Networks** for reliability, modularity and competitive selection



NASA Wireless Avionics Community of Practice **(Internal leveraging)**



JSC/EV George Studor

Internal Website Live June 6th, 2010

Purpose: Mature NASA Wireless Avionics Connections technology and applications through an agency-wide forum to share information and capture knowledge, under the Avionics CoP.

Scope:

- Limited to on-vehicle and vehicle proximity RF wireless*
- Facilities used for vehicle test and check-out and wireless systems eval.
- Support Avionics CoP in reporting and issues identification/clarification.
- Wireless Avionics CoP is not a working group. Occasional issues may require CoP to help find experts to man teams external to it.
- Within a range that wires might otherwise have been run, but functionality or practicality may favor wireless.

Members: Lead: JSC/George Studor
Center POCs at each NASA center



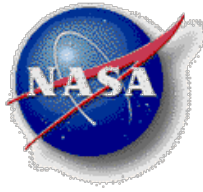
SBIR/STTR Phase 2 Project Search

(Cross-Agency Leveraging)

At approximately \$1.3M for each 2 year project... there is a lot being invested.. Note: other agencies not listed: DOT, NIH, etc....

And I haven't listed the many Phase 1 Projects...

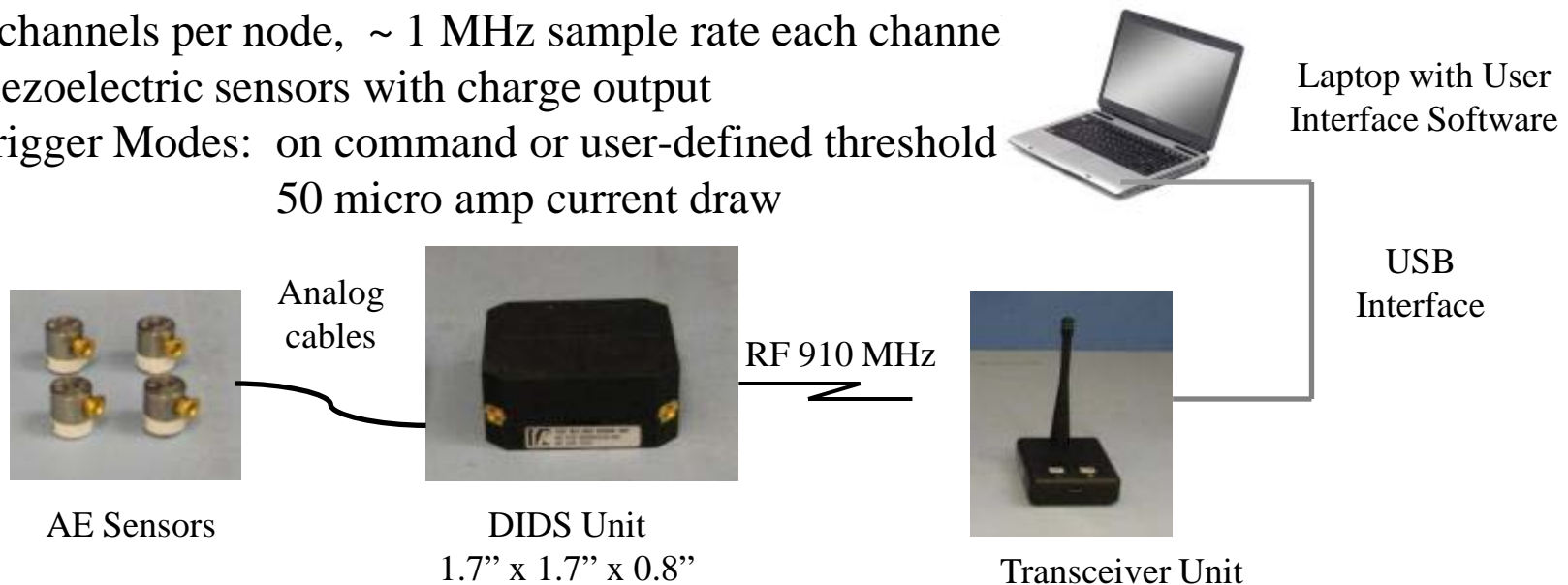
| Agency | Sensors | Networks | RFID | Avionics | Radio | Antennas | Total |
|-----------|---------|----------|------|----------|-------|----------|-------|
| Air Force | 15 | 7 | 3 | 10 | 12 | 17 | 64 |
| Army | 12 | 11 | 9 | 0 | 8 | 17 | 57 |
| CBD | 1 | 1 | 1 | 0 | 0 | 0 | 3 |
| DARPA | 5 | 5 | 2 | 3 | 1 | 10 | 26 |
| DHS | 11 | 4 | 4 | 0 | 0 | 0 | 19 |
| DOE | 19 | 2 | 0 | 0 | 0 | 0 | 21 |
| MDA | 5 | 2 | 0 | 11 | 2 | 3 | 23 |
| NASA | 31 | 11 | 5 | 9 | 7 | 6 | 69 |
| Navy | 20 | 8 | 2 | 10 | 18 | 23 | 81 |
| NIST | 4 | 0 | 0 | 0 | 0 | 0 | 4 |
| NSF | 17 | 2 | 7 | 0 | 2 | 4 | 32 |
| OSD | 3 | 2 | 0 | 0 | 1 | 2 | 8 |
| SOCOM | 0 | 1 | 0 | 0 | 1 | 2 | 4 |
| Total | 143 | 56 | 33 | 43 | 52 | 84 | |

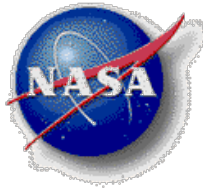


ISS Leak Location System

Let's make it smaller, faster cheaper

- **STEP 1: On-Orbit DTO to Characterize ISS AE Environment**
- **Use Distributed Impact Detection System (DIDS) – Phase 2 SBIR Project:**
(works for leaks too)
- Record acoustic emission or acceleration “events” on structures or through air
 - Window of data is recorded upon detection of an event.
 - Event characterized by exceedance of programmed threshold value .
 - Software can perform a “forced trigger” to command a data take
- System characteristics:
 - 4 channels per node, ~ 1 MHz sample rate each channel
 - Piezoelectric sensors with charge output
 - Trigger Modes: on command or user-defined threshold

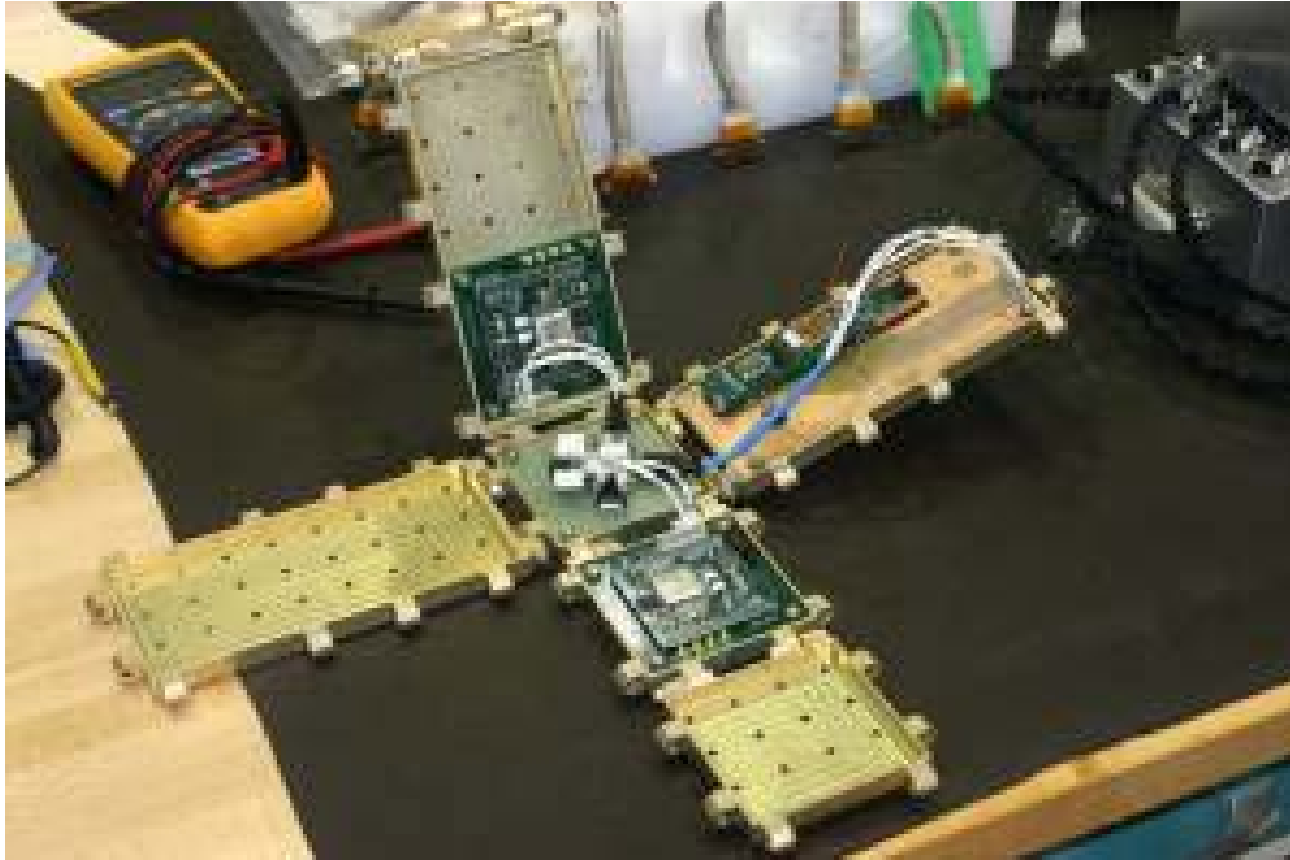




Wireless Spacecraft

Several AFRL SBIR awards for CubeSats

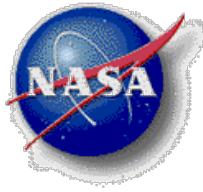
Start with reducing the 15 pin connectors in a typical Cube-sat



SDM – Satellite Data Module

ASIM – Applique Sensor Interface Module

XTED – eXtended Transducer Electronic Datasheets



New Tool Box for Maintenance Work

Data Loggers – wireless and non

Wireless Sensor Network

- Standalone deployable Central Node

Active & Passive Sensor Tags

- Interrogators for Both Tags

Smart Bar Code/RFID Inventory system

- Stored Information and Location

High Data Rate Node:

- Wireless Work Control iPad – Massive Storage
- High res photos/drawings
- Wireless Location (Internal & External)
- On-board link to Vehicle Systems

Rechargeable or Long-Life Batteries

Scavenge Power options for in-flight

Plug-and-Play Antennas

RF Troubleshooting Equipment



.....Plus Flashlight and Screwdriver



Avionics Bays are Typically Crowded

Aerospace Sensing is a common need...

Aerospace Sensors Working Group

(NASA-lead, Industry and other Agency attended)

- Practical Ways to get across bulkheads without connectors
- Communicate reliably in a harsh environment with extreme multipath (but at least it is short range and not dynamically changing)
- Modular access points to change and upgrade configurations





Power Scavenging for Wireless Standalone Sensors

EADS Thermal Scavenging Sensor for VHM

Aug 12, 2010

Forwarded to me from Embraer rep on AVSI Team...
stay connected through Working Groups and informal contacts.



<http://www.newelectronics.co.uk/article/26986/EADS-reveals-developments-in-aerospace-energy-harvesting-.aspx>

Let's Make the Effort to Work Together!!